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WADC TECHNICAL REPORT 59-226

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JUNE 1959

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WRIGHT AIR DEVELOPMENT CENTER
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Project No. 7218
Task No. 71719

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FOREWORD

The vehicle described in this report was designed, constructed, and tested as part of Project "High Dive," under Project 7218, Task 71719, "High Altitude Escape Studies." The project was initiated and supervised by Captain Henry P. Nielsen of the Aero Medical Laboratory, WADC.

The successful completion of the gondola development, resulting in a superior balloon lifted vehicle suitable for a variety of high altitude research studies, was due to the effort and cooperation of many people at various ARDC centers. The authors therefore wish to thank the following personnel for their contributions to this development:

WADC

Electronic Sub-Systems -
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Personnel of other centers who made valuable contributions were Major Richard Braun of the Air Force Cambridge Research Center who selected and procured the balloons, and Lt. Alfson and Lt. Neal of HADC who rendered invaluable service in launching the gondola on its test flight.

ABSTRACT

Balloon borne vehicles are well suited for use as a means of lifting parachutists to very high altitude for test jumping.

The design, fabrication, and testing of a vehicle, developed at the Wright Air Development Center for this purpose, are discussed in this report. Included are presentations of novel designs for a pressure-retaining hatch and an energy-absorbing parachute landing device.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

Andres I. Karstens

ANDRES I. KARSTENS
Colonel, USAF (MC)
Asst. Chief, Aero Medical Laboratory

INTRODUCTION

As a result of various studies concerning the problems of high altitude escape (1, 2), a program was initiated to conduct live bailouts with a stabilization parachute from altitudes between 60,000 and 100,000 feet. Since live jumps in this altitude range were not feasible with aircraft, it was necessary to develop a balloon gondola to carry the jumpers.

The special mission of project "High Dive," as the bailout program was called, required a crew of trained parachutists to operate the gondola. It would have been difficult and time-consuming to train jumpers as balloonists or vice-versa. Therefore, a mission profile was planned that would take advantage of the parachute training of the crew and at the same time minimize their lack of ballooning experience. The sequence of events was planned as follows:

(1) The gondola would be launched from Holloman AFB, New Mexico, by the AFMDC Balloon Unit and would float over the instrumented range.

(2) At an altitude of 25,000 feet, a pressure regulating valve would close the gondola to the outside atmosphere, maintaining a cabin altitude of 25,000 feet (5 psia) up to the decompression time.

(3) When the gondola reached maximum altitude, the men would test their pressure suits and then valve-off the gondola atmosphere to equalize the interior and exterior pressure.

(4) The jumper would move to the hatch, remove it, and jump.

(5) After the jumper had left the gondola, the pilot would initiate the balloon cut-down sequence. The automatic sequencing would be as follows:

a. The 168 and 34-foot wire antennas (for high frequency communication) hanging from the gondola would be severed and allowed to fall away.

b. A pyrotechnic cutter would then separate the gondola from the balloon.

(6) The gondola would free-fall on a 14-foot diameter stabilization parachute to 20,000 feet, where the 64-foot main recovery parachute would be deployed.

(7) The pilot would disconnect his harness, move to the open doorway and jump from the gondola (about 18,000 feet).

(8) The gondola would continue to descend. When it touched down, an impact switch would fire pyrotechnic releases on half the risers, thus spilling the parachute and preventing surface winds from overturning and dragging the gondola.

This mission profile determined the general configuration and various special design features of the gondola. There were two main design considerations: multi-stage parachute recovery of the gondola from ceiling altitude; and the need to depressurize the gondola at altitude and operate the system in conditions of near-vacuum.

The decision to rely on parachute recovery of the gondola resulted in some unique design features. There was no need for a valving system in the balloon or for large amounts of ballast, both of which are needed to fly a balloon back to the ground. A multi-stage parachute system of high reliability, compactness, and safety was developed. This parachute system shows promise as a recovery system for any gondola having a suitable aerodynamic shape. A method of absorbing parachute landing forces that could be used to great advantage on any heavy parachute load was developed. Finally, a rugged but lightweight structure was evolved using the principles of aircraft structural design.

The requirement for depressurized operation of the gondola and the exit at altitude of a man in bailout gear and inflated pressure suit dictated these design features: a spacious gondola interior; visibility and accessibility of instruments and controls to a man in an inflated pressure suit; a large hatch for easy exit of the jumper.

The use of a multi-stage parachute recovery system on the gondola offered an additional safety feature. If trouble at altitude should occur (e.g., hypoxia or explosive decompression) the gondola and occupants could be brought down in a minimum time by a ground controller. An ECG telemetering system was installed in the gondola so that the ground control personnel could keep a constant check on the condition of the gondola crew. The cut-down and parachute deployment system could be actuated by ground command if an emergency should arise.

GONDOLA DESIGN REQUIREMENTS

From analysis of the projected mission profile as well as a study of previous balloon gondola flights, it was possible to arrive at realistic structural and equipment requirements.

Structural requirements were found to be as follows:

(1) The gondola should be a pressure vessel capable of withstanding a pressure differential of 5 psi with a safety factor of 3.0.

(2) The shape of the gondola should insure aerodynamic stability during drogue chute descent.

(3) The gondola should be capable of withstanding a main parachute opening shock of 3 g with a safety factor of 2.

(4) The gondola should have provisions for absorbing the kinetic energy of the main chute descent upon striking the ground (about 28 ft/sec).

(5) The entire gondola must be so designed as to survive at least two successive landings on the rugged terrain in the Holloman area without major repair or modification.

(6) The assembly must be as lightweight as possible.

The equipment required in the gondola was found to be:

(1) Oxygen - sufficient oxygen to supply two men for 6 hours.

(2) Communications - Inter-Com, HF and VHF two-way ground-air voice communication, an altitude coder (HF), an ECG telemetering system (VHF), and a ground command cut-down system (HF and VHF).

(3) Camera system - sequence still photos of balloon development to floating altitude; terrain below for trajectory plot; pulse camera record of instrument panel; high speed camera coverage of the first ten seconds of the jumper's fall; cinema coverage of the behavior of the gondola parachutes.

(4) Instruments - cabin and outside altitude, rate-of-climb, temperature inside and out, inside humidity, contents and pressure of the liquid oxygen converters.

(5) Power - a supply sufficient to run all the equipment over the longest time of flight and to actuate all the pyrotechnic devices with a reasonable factor of safety.

(6) Air-Conditioner - a carbon dioxide and water vapor absorbing system to keep the gondola cabin environment habitable for a 6-hour flight period.

DESIGN, FABRICATION, AND TEST

Spherical Shape

The initial approach to the design of the gondola was adversely influenced by previous balloon gondola configurations. All previous gondolas had served simply as containers for a habitable atmosphere, especially for the maintenance of interior pressure. Since a sphere was the optimum shape for a pressure vessel, this was inevitably the chosen configuration (Fig. 1).

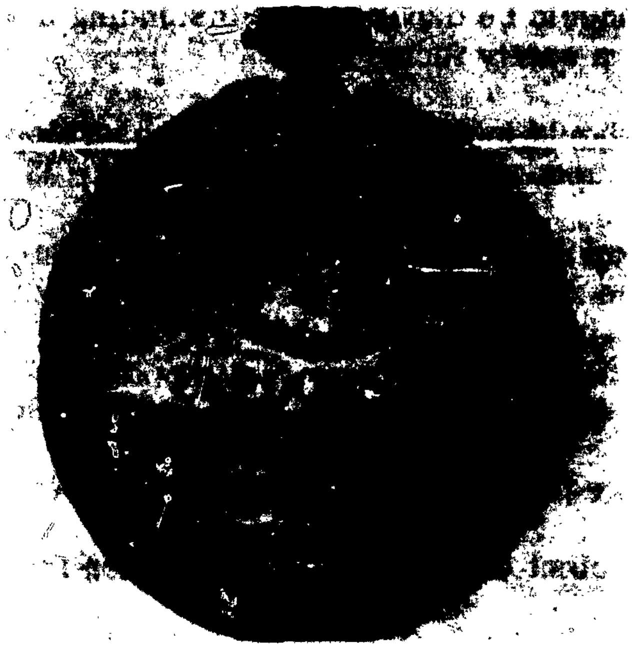

FIGURE 1 - Seven Foot Diameter
Spherical Gondola, Fibreglas

The first design was nearly completed when it became obvious that a spherical gondola could not be made to meet the requirements of the mission profile. The sphere's double curvature made fabrication difficult and rendered the design of a large, lightweight, efficient hatch and hatch-frame almost impossible.

The spherical shape was also very inefficient in the amount of useable space it contained. Head room was lacking for a standing occupant and equipment placement was difficult, due to the curvature. (See Fig. 2.)

Since a landing shock absorbing device was necessary to absorb the energy of the descent under the main cargo chute, much work was done to tailor various decelerator systems to the sphere. It was found that the curvature again made the problem more difficult and the solution unnecessarily complicated.

The sphere was fairly stable aerodynamically, however. A test drop using a full size (7-ft diameter) sphere was made at Holloman AFB, N.M. This dummy gondola (Fig 3) was instrumented to record oscillation and accelerations during the chute descent and recovery chute deployment. It also was equipped with motion picture cameras pointing up into the chutes, straight down, and horizontally. The sphere was flown to 89,000 feet on a 128-foot polyethylene ballon. The recording instruments and cameras were started and the ballon was cut loose. The records and film showed the descent to be acceptably stable. The main parachute opening shock at 20,000 feet was about 3 g. The indicated air speed of the drogue chute descent was about 90 knots.

FIGURE 2 - Interior of Spherical Gondola

Although the sphere was an ideal pressure container and its aerodynamic stability was acceptable, it was a poor choice because its structural and operational limitations far outweighed its advantages.

Cylindrical Shape

It was decided to base the design on a right circular cylinder, and to make use of any unconventional methods of design and fabrication to affect major weight savings. (See Fig 4.)

The basic configuration was a seven-foot diameter cylinder, six feet high. The remainder of the structure and accessories were designed to meet the various requirements of pressurization, parachute opening shock, aerodynamic stability, landing shock, cabin environment, communications, and operational convenience.

Landing Gear

Since the gondola would be recovered by a large cargo parachute, some device was needed to absorb the landing shock when the gondola struck the ground.

F.'GURE 3 - Dummy Gondola

FIGURE 4 - Complete Gondola System with Launch Cart

The terminal velocity of the gondola with recovery chute deployed would be approximately 25 feet per second. The probable weight of the gondola at this time would be about 900 pounds, assuming a normal flight profile. The maximum possible weight would be about 1400 pounds, assuming an emergency situation in which the two occupants might decide to ride the gondola to the ground on the recovery parachute.

Since the emergency situation would be the critical one from the standpoint of landing deceleration forces imposed on the occupants, the 1400-pound weight was used in the design of the deceleration system. A maximum deceleration of 12 g and a rate of onset of no more than 700 g per second were chosen as limits which the occupants could be expected to undergo with no chance of injury.

Several possible systems of deceleration were considered, of which the most promising seemed to be:

(1) Air Bag - A large inflated bag could be attached to the bottom of the gondola. When the gondola struck the ground, the air would be forced through an orifice, dissipating the kinetic energy.

(2) Pneumatic or Hydraulic Shock Absorbers - These would operate in a manner similar to the shock absorbers of an aircraft. The force of the gondola striking the ground would force air or hydraulic fluid through an orifice to dissipate energy.

(3) Crushable Plastic Foam - The bottom of the gondola could be fitted with a mass of material such as Styrofoam, a Dow Chemical Co. product. This material is capable of absorbing energy by crushing and can be made in various densities and shapes.

(4) Metal Cutting Deceleration - This system would use the energy dissipating capacity of metal cutting. The motion of the gondola could be used to move metal legs in relation to cutters fixed to the gondola structure, thus cutting grooves in the legs and dissipating the energy of the gondola by the shearing and friction forces developed in the cutting process.

In considering the relative merits of these four systems, several factors had to be considered. It was essential that the system be lightweight, above all; capable of operating under a wide variation of temperatures; give a reliable deceleration pattern; and be capable of operating if the gondola is oscillating or drifting when it strikes the ground. If material failure were used to dissipate energy, the material would have to be easily replaceable. In addition, it could not interfere with the aerodynamic characteristics of the gondola.

The air bag system was discarded because it would be too bulky, thus aerodynamically undesirable, and probably incapable of taking appreciable side loads.

The pneumatic or hydraulic shock absorbers were found to be undesirable because of the anticipated operation at extremely low temperatures, as well as the likelyhood of their being excessively heavy.

The crushable plastic foam decelerator looked promising at first, but was discarded for two reasons: the material tended to crack under impact rather than crush, and the material would be quite difficult to attach to an efficient gondola shape, that is, it would require a flat gondola floor to transmit the landing loads. However, General Mills, Inc., in their gondola design for project "High Dive," did adopt the Styrofoam decelerator with very good results (3).

The metal cutting decelerator was chosen for the job because it not only met all of the requirements but could also be designed and tested easily.

It was found that an aluminum alloy tube with a diameter of 3.50 inches and wall thickness of 0.091 inches would be sufficient to take most side loads imposed by landing in heavy surface winds. The total vertical deceleration distance would be about 14 inches for a deceleration of about 10 g at a gondola sink rate of 27 feet per second.

A test rig was fabricated to simulate the load on the decelerator legs. It consisted of a box to hold lead shot underneath which a leg holder was attached. Four tool-steel cutters 0.40 inches wide were set into the leg holder and spaced 90° apart. The aluminum tube to be tested was inserted in the leg holder. The test cart was restrained by four sets of rollers to a set of vertical rails. The depth of cut was adjustable by the insertion of shims between the cutter and holder. An accelerometer was attached rigidly to the cart to record the acceleration pattern when the cart was raised to a predetermined height and dropped. The decelerating leg would contact the ground and the cart with its load of lead shot would force the cutters along the surface of the leg and broach it (Fig. 5).

It was found that a given depth of cut gave a fairly constant deceleration at from 0 to 27 feet per second. As the velocity decreased, the acceleration showed a slight increase.

The depth of cut, test weight, initial velocity, and material to be cut were varied to determine the combination necessary to produce the desired deceleration pattern. The results of these tests are shown in Table 1.

It was found that over the range of test conditions used, the cutting system would produce an approximately constant cutting force for a given material and depth and width of cut. The force chosen for design was 3000 pounds per leg.

FIGURE 5 - Drop Test of Metal Cutting Deceleration System

Assuming four legs equally spaced around the gondola, this would give a total decelerating force capacity of 12,000 pounds. With a landing weight of 1200 pounds this stopping force would give a deceleration of about 10 g if all four legs operated. With a landing weight of 900 pounds, in other words an unoccupied gondola, this would give a deceleration of 15 g, but still only a force of 3000 pounds per leg would be imposed on the gondola structure.

The final design called for four cutters 0.40 inches wide taking a 0.021 inch cut in 24 ST3 aluminum tubing. It was found that 61 ST3 tubing was unsatisfactory since it produced a continuous chip. The 24 ST3 tubing, being harder, produces a discontinuous chip which is expelled neatly from the cutter without jamming. In order to obtain a controlled rate of onset of the decelerative force, it was originally thought that a tapered-depth approach for the cutter would provide a slowly increasing depth of cut and thus a controlled rate of onset. This proved impractical due to the elasticity of the tube, which would spring inward away from the cutters and then deflect outward again instantly. This completely eliminated the effect of the taper. The solution was to maintain a constant depth of cut and provide a tapering width of cut. This proved very successful, giving a rate of onset of 665 g per second for the final configuration at 27 feet per second and with a cart weight of 300 pounds.

TABLE 1

PARACUTE LANDING DECELERATOR - PROJECT "HIGH-DIVE" BALOON GONDOLA

Test	Drop Ht. (Feet)	Average Decel. (g)	Rate of Onset (g/sec)	Duration (sec)	Depth of Cut (in.)	Material	Drop Cart Weight (pounds)
3	6	11.2	1115	0.07	0.022	24ST3	300
4	9	11.2	2000	0.08	0.022	24ST3	300
7	10	10.0	1050	0.094	0.023	24ST3	300
8	10	10.0	1015	0.094	0.023	24ST3	300
9	10	9.8	985	0.075	0.022	24ST3	300
10	10	9.8	1560	0.080	0.022	24ST3	300
11	6	10.9	465	0.080	0.022	24ST3	300
12	6	10.3	354	0.085	0.022	24ST3	300
13	10	10.4	930	0.080	0.023	24ST3	300
14	10	12.1	700	0.080	0.022	24ST3	250
15	6	10.8	1860	0.065	0.023	61ST4	300
16	10	10.8	1330	0.085	0.023	61ST4	300
17	10	10.8	665	0.095	0.023	61ST4	300

The final landing gear design incorporates a removable cutter assembly operating on a pregrooved, 3.5-inch 24 ST3 aluminum alloy tube. The tube is attached to a wooden base, and may be replaced after each flight. The "foot" of the landing "leg" is a section of a 10-inch radius sphere, 15 inches in diameter and 4 inches high made from Fiberglas and glued to the wooden base. The foot has a smooth surface to cut down on the bending moments imposed by a cross wind landing followed by a sudden stop.

Landing Gear Supports and Floor Structure

The loads imposed on the landing gear under extreme conditions of operation governed the design of the landing gear supports and floor structure. Preliminary calculations showed that the structure would have to withstand compressive loads of over 7000 pounds and bending moments of over 25,000 inch-pounds.

The landing gear supports were made as webbed and flanged structures with 3-inch flanges from 0.091 61 ST6 aluminum alloy. The cutter assemblies screw into the tube holders. The cast tube'holder assembly is supported by 1.25-inch diameter, 0.049 thick 24 ST3 aluminum alloy tubes on either side that tie into the floor structure tangentially to absorb lateral bending loads. (See Fig. 6.)

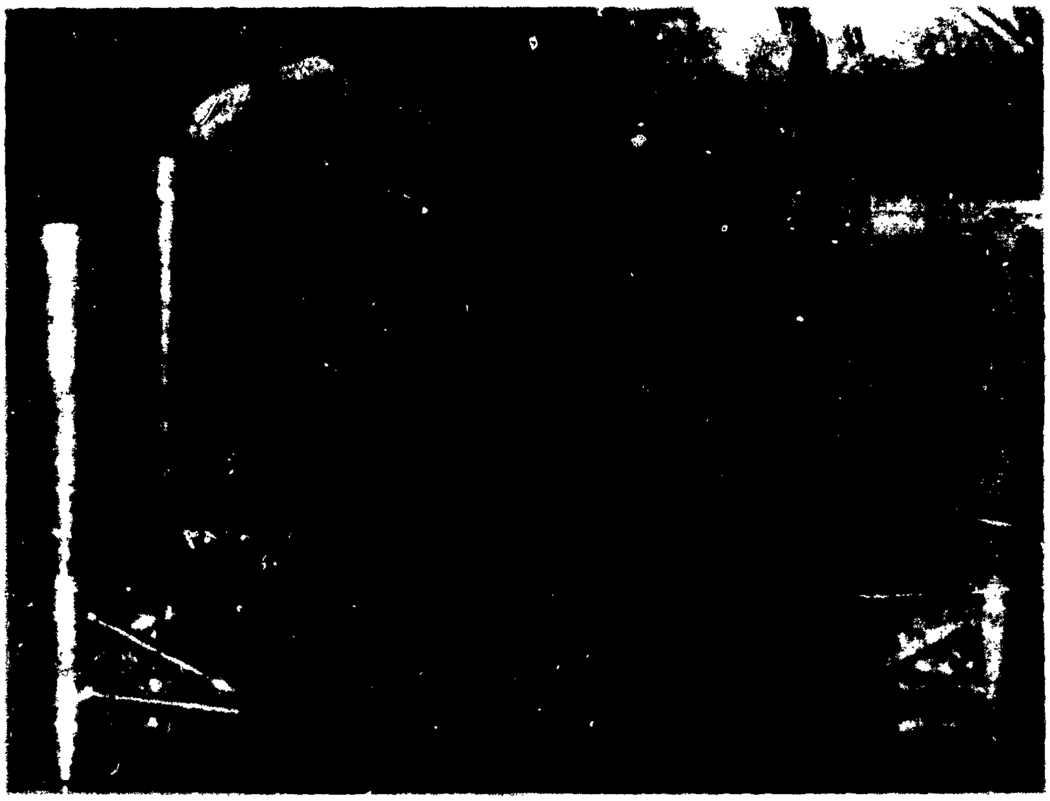

FIGURE 6 - Static Test Of Floor Structure and Gondola Seats

The loads from the landing gear supports are passed through reinforced portions of the skin to built-up box sections of 0.051 24 ST3 aluminum alloy. These structures introduce the loads into the floor structure.

The floor structure (Fig. 6) is composed of four basic elements: (1) a "C" section circling the inside of the gondola skin, reinforced at intervals by stiffners; (2) an "X" structure of box beams, 3 inches wide by 3 inches high, stiffened at intervals along the beam; (3) a square of box beams, identical in construction to the above; (4) "C" section struts, acting as secondary support structure for stiffness of the outside ring and secondary equipment attachment. These elements are tied together with gusset plates and 5/32-inch rivets, or bolts in the case of the landing gear fittings. The entire floor structure was made from 0.051-inch 24 ST3 aluminum alloy.

The design of the floor structure was based upon two special considerations: the behavior of the beams as combined columns and beams under side landing loads, and ease of equipment attachment. This made the "box" cross section ideal. The final floor structure is very adaptable, strong, and lightweight.

Half of the gondola floor structure is covered with a wire netting to prevent loose objects from falling out of reach during flight. The other half of the floor is covered with honeycomb Fiberglas panels that are easily removable for maintenance (Fig. 7).

FIGURE 7 - Gondola Floor Structure With Seats and Fibreglas Honeycomb Floor Boards Attached.

The honeycomb material is made from 1/4-inch hexagonal cells with a sandwich thickness of 0.0345 and a face thickness of 0.032 (USAF 11-D PE 1/4 112-40). This material stood up well under altitude and impact tests.

Seats

The seats had to conform to two unique requirements. They had to withstand very high landing impact loads without any deformation that could injure or trap the crew; and they had to be easy to get into and out of with bulky jump equipment and pressurized suits. It was thought that the seat would have to be of an open construction to permit ease of exit. In order to obtain the required stiffness, two T section channels were run down the back and bottom of each seat. A double panel on the bottom provided good load distribution into the instrument panel for further rigidity. The seats and the panel are easily removable as single units for special flights. Each seat is provided with adjustable head rests, lap belts, parachute shelf and shoulder harness. The seats are to be used with a back pack parachute and seat kit combination (Fig. 7).

Bottom Pressure Bulkhead

In order to provide a minimum of interference with the landing gear, it was decided to make the gondola with a flat bottom. It was planned to fly with about 5 psi internal pressure. Therefore it was decided to design for 15 psi differential.

Preliminary calculations showed that the pressure on a flat bulkhead would inflict greater stresses than the floor structure was designed to carry. The floor structure could have been revised to carry the pressure load. However, this would have meant less flexibility in equipment placement and would add greater weight. (General Mills designed a sandwich construction pressure floor, at about 150 pounds extra weight.)

It was decided to retain the pressure at the bottom by a rubberized nylon bag. The bag was to inflate under pressure to a rounded shape for pressurization efficiency and to deflate and be pulled up flat under the gondola for a clean landing. This had a bonus feature in that the bag was electromagnetically transparent and therefore permitted the installation of the VHF antennas within the bag.

In the final configuration, the total bag was formed of two separate bags, joined at the pull-up points. Each bag had 16 panels and was separated by reinforcing strips into 80 roughly equal "unsupported" areas to cut down the tendency of the "free" material at a distance from a more rigid hem to swell up at the expense of the more tightly bound material. The panels of one bag were offset with respect to the panels of the other. A loose polyethelene lining was used as a gas barrier. The bag was made with a 46.8-inch radius of curvature

at the base and a 24.0-inch radius at the hem. The inside hem diameter was 84.0 inches.

The base fabric chosen for the bag was U.S. Rubber Fiberthin No. 79628. This fabric is a vinyl coated nylon fabric woven with a "rip stop" construction, i.e., it resists tearing in bi-axial tension. The fabric seemed ideally suited to pressure barrier construction, being very tough, lightweight (9 oz per square yard), and strong (385 pounds per inch warp by 350 pounds per inch fill).

The panels were sewn together with french seams and treated with sealant. After stitching, 3-inch cover strips were fastened across the seam on either side with adhesive to achieve over 100% joint efficiency. The hem of the bag, where the bag was fastened to the skin of the gondola, contained two pieces of nylon webbing, MIL-W-4088B, type VI, for bearing strength and the polyethelene lines. The hem assembly was also french stitched. In order to carry the load into the skin, the skin was reinforced with 0.051 75-S-T clad aluminum- alloy strips welded on the inside and 10/32 steel aircraft bolts were placed through the hem into the skin every 1-1/2 inches. An aluminum alloy strip 0.032 inch thick circling the outside of the hem acted as a continuous washer. The bolts were torqued to 90 inch-pounds and the load was transmitted frictionally by the bag to the skin. Pressure sensitive tape plus room temperature vulcanizing silicone rubber strips (laid on the outside skin) were used as sealing agents.

Due to difficulties in quality control, design, and sealing, the concept of a pressure retention bag was abandoned (see the section on testing). It was decided to utilize a lightweight metal structure as a bottom pressure cap. It was felt that the cap could be made strong enough to withstand all pressure loads and flimsy enough to crush on ground impact without seriously impairing the effectiveness of the decelerator legs.

The construction of the bottom pressure cap very closely approximates that of the top (see the section on upper structure). The spinning on the bottom has a spherical radius of approximately 13 inches and is tangential to the 45° cone. The cone skin is 0.032-inch 75 ST6 aluminum alloy. The cone butts against the cylinder and a cap strip joins them. The skin of the cylinder is reinforced by triangular braces spaced along the back-up strip between the strip and the bottom of the "C" section ring. The holes drilled for the 10/32 bolts were used to fasten the cap and the entire cap may be removed and replaced after each flight.

Upper Structure (Fig. 8a)

The upper structure of the gondola was designed to meet several requirements. The main body of the gondola was a right circular cylinder. It was necessary to close it at the top, providing strength to take both the pressure stresses and parachute opening shock loads to be imposed on the gondola. It was apparent that the shape of the top would affect the aerodynamics of the

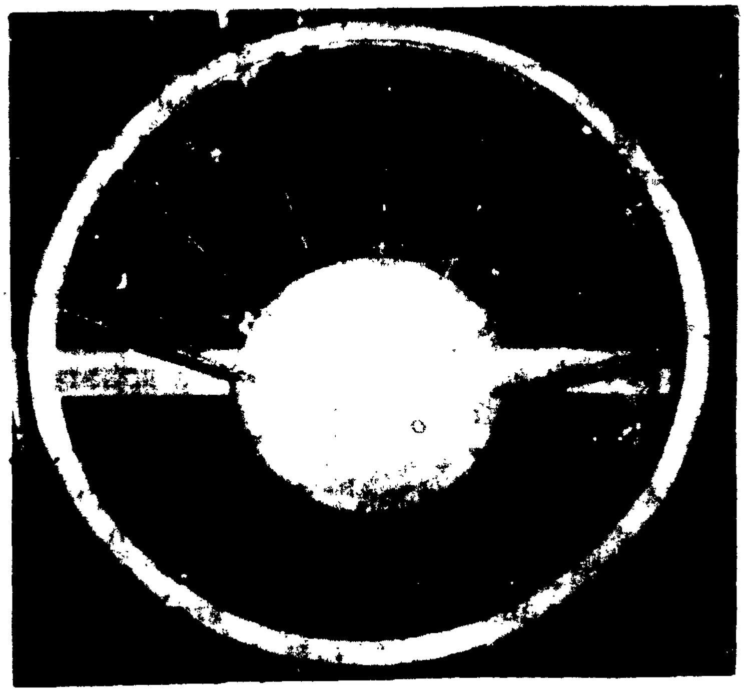

FIGURE 8a - Bottom View of Upper Structure Showing 7 Foot Diameter Ring, Stringers, and Spun Pressure Cap

gondola-parachute system. It was decided that the most economical approach in respect to weight was to design the pressure vessel to maximum efficiency and to add a thin Fiberglas fairing to give the optimum aerodynamic shape (Fig. 8b).

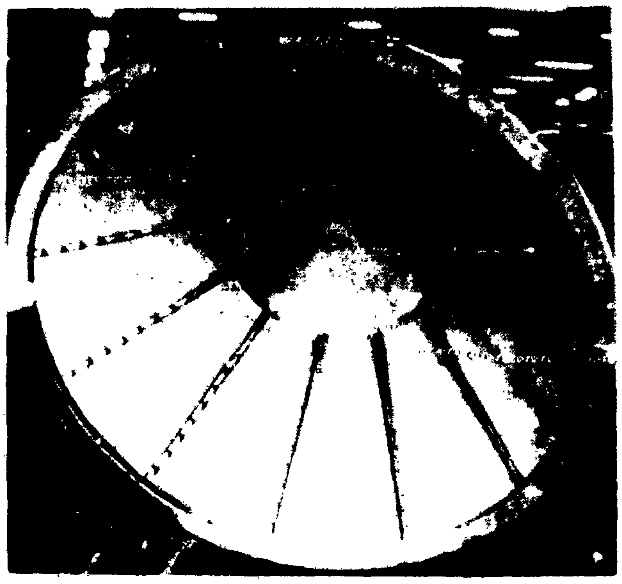

FIGURE 8b - Interior View of Upper Structure With Skin Attached

The top structure consisted of a 45° cone attached at the top of the 7-foot diameter cylinder and truncated at the 3-foot diameter. A reinforcing ring at the point of attachment to the cylinder was added to bear the shear stress due to the discontinuity at the 7-foot diameter and also to distribute the opening shock loads from the upper structure stringers to the cylindrical skin. The cylinder would then transmit the opening shock to the floor structure.

The stringers are connected directly from the 7-foot diameter ring to the 12 parachute riser brackets. The brackets are mounted around a 3-foot diameter "C" section ring which serves the dual purpose of resisting the horizontal component of the parachute opening shock and reinforcing the point of discontinuity at the connection between the 45° cone and spherical pressure cap. A cylindrical can, 7 inches high, is mounted to this ring to contain the gondola recovery parachute pack. Six of the twelve riser brackets have a built in release mechanism operated by electrical squibs. These are actuated by gound impact to release half of the parachute, thus preventing the gondola from being dragged in high winds. A spun pressure cap, a section of a sphere of 6 foot radius, closes the pressure vessel at the 3-foot diameter.

Riveted seams were used throughout the pressure vessel, since the high strength aluminum alloy (75 ST6) used for the skin could not be welded. In addition, it was thought that welds in aluminum pressure vessels were considerably unpredictable as to flaws, from both strength and leakage standpoints. The riveted seams were sealed with a standard aircraft pressure cabin sealing compound.

Hatch

Since the jumper was to exit through the hatch at floating altitudes in excess of 50,000 feet and would therefore be pressurized, a hatch as large as possible was needed for safe, easy egress. Both the reduction in mobility in an inflated pressure suit and the man's bulkiness due to heavy clothing, equipment, and parachutes, contributed to this need.

There are basically two types of hatch construction that are readily apparent. One is the rigid-frame, rigid-hatch type in which the opening is surrounded by a frame capable of transmitting the tension in the pressure vessel skin around the opening and bearing the load imposed by the hatch. The hatch itself is a rigid structure, usually flat, which acts to retain the gondola interior pressure much as a cork in a bottle neck. This rigid frame, rigid-hatch arrangement was found to be highly inefficient weight-wise and therefore undesirable. The frame for a reasonably large hatch area would have to resist extremely high bending loads of up to 630 pounds per inch in the circumferential direction of the cylinder. Perpendicular to this load is the bearing load imposed by the hatch itself. For a rectangular hatch 5 feet high and 3 feet wide, the average bearing load imposed by a 15 psi pressure differential is about 170 pounds per inch. Any hatch frame capable of resisting these combined loads with a reasonable factor of safety would be extremely heavy. Furthermore, the hatch itself, being obliged to take the pressure load in bending, would also be unduly heavy and cumbersome.

A second hatch type is one which carries the skin tension directly across itself. The ideal hatch is one which, when it is in place, acts only as an

integral part of the pressure retaining membrane, and yet is easily removable. This hatch would weigh no more than the pressure vessel skin it replaces.

It was therefore desirable to approach the "ideal hatch" as closely as possible. The final design consisted of a frame riveted to the gondola skin and projecting over into the hatch opening. Set into the projecting lip were short, one-half inch diameter aluminum pins spaced four inches apart around the periphery of the hatch opening. When the hatch was in place, the pins rested in slotted holes machined in the hatch edge. The hatch was a cylindrical section of gondola skin with a frame riveted around its edge. The skin tension was then effectively transmitted by the pins from the gondola skin through the hatch frames, and across the hatch skin.

Sealing was accomplished by bonding to the hatch a silicone rubber gasket which overlapped the frame around the opening when the hatch was set in place.

The total weight increment due to the addition of the hatch was 25 pounds.

Fairings

Early in the gondola design, it was decided to concentrate on an efficient structural design, and to add fairings to achieve a good aerodynamic shape. This was the opposite approach to that of other workers (3).

Because of its high strength-to-weight ratio and ease of fabrication, Fiberglas was chosen as the material for the fairings. The fairing shapes were determined from wind-tunnel tests. The fairings were constructed of two laminations of Fiberglas cloth with overlap and resin content held to a minimum. Although the fairings weigh only 25 pounds a piece, when bolted to the gondola they become quite rigid (Fig. 8c).

FIGURE 8c - Gondola Upper Fairing-Fiberglas

Atmosphere Control

The gondola operates on a purified oxygen atmosphere. Liquid oxygen in two 5-liter converters supplies the crew during the purging operation while nitrogen is being removed from the gondola. After a 95 per cent oxygen atmosphere has been established (one hour), the crewmen remove their visors and breath the cabin oxygen. A small axial flow blower circulates the cabin atmosphere through the air conditioning chemicals ("Barolyme" for carbon dioxide absorption and Linde "Molecular Sieve" for water vapor absorption).*

The liquid oxygen converters are topped off and the gondola ascends with the dump valve open. At 25,000 feet the dump valve is closed and the gondola sealed at 5 psia. At floating altitude the crew goes onto the liquid oxygen converters and decompresses the gondola to 45,000 feet cabin altitude and tests pressure suits. If all is well, decompression continues to the floating altitude. The hatch is removed and the jumper switches to bailout supply and exits. The pilot remains on liquid oxygen from the converters till he leaves the gondola at lower altitudes. In the event of a leak the converters can supply oxygen directly into the cabin atmosphere.

Electrical System

Function — The WADC gondola electrical system was designed to provide communications, flight control, photo-recording of flight experience, climate control, and physiological data.

Two-way communication is available with the ground control station, tracking and rescue aircraft, and between pilot and co-pilot.

The system provides control of flight during ascent and at altitude, and control of the mechanism of parachute deployment during different phases of the descent. The most important flight control equipment for the gondola is that which pertains to balloon cut-down, ballast and ballast control, and parachute deployment.

An instrument console located between the pilot and co-pilot was designed to be within easy reach of either man and to provide an unobstructed view of all switches and instruments from either seat.

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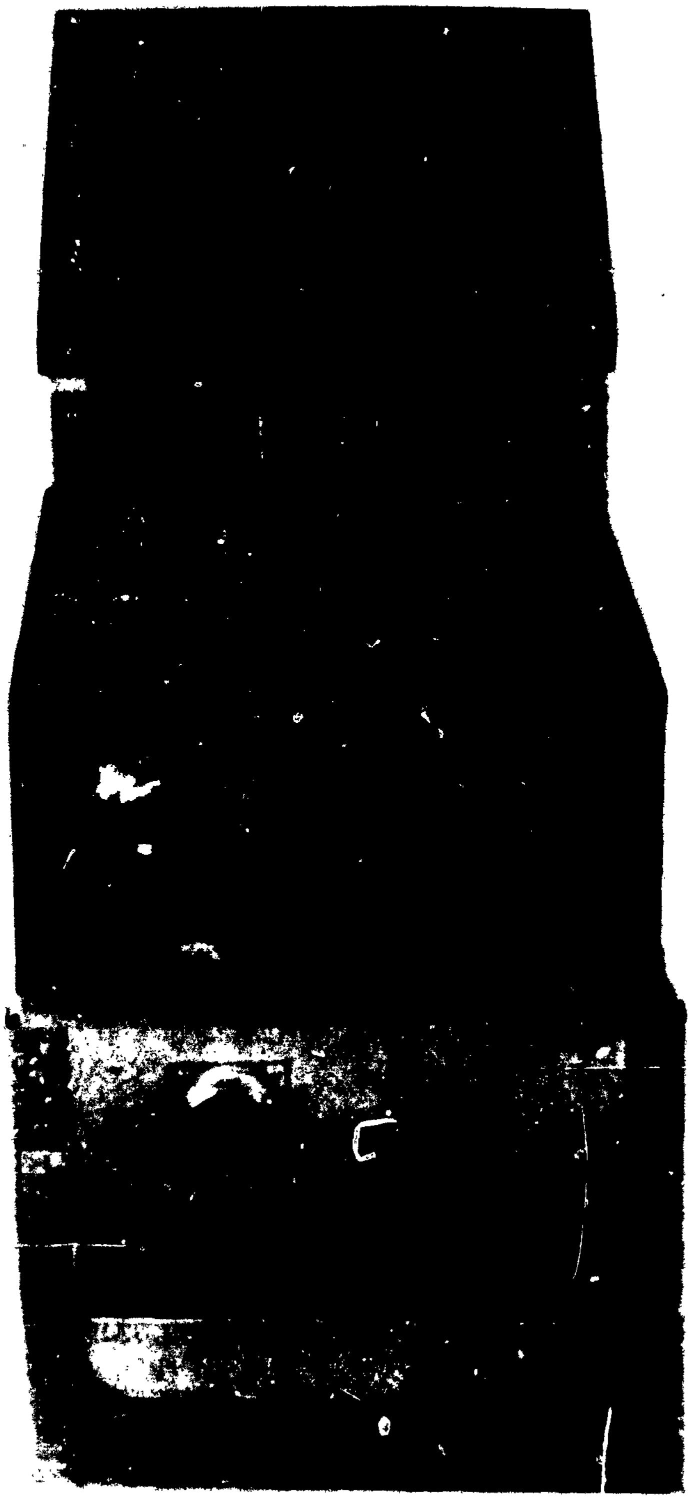
* It was found that the "molecular sieve" absorbs about 1.5 pounds of H_2O in 12 pounds of sieve, which is sufficient to control fogging or frosting upon decompression.

Communications System

Communications equipment and controls are mounted on the horizontal rack of the console. The system (Figs. 9A and 9B) consists of the following:



Interphone — Pilot and co-pilot helmets, type MA-2, contain a dynamic microphone, type M-32/AIC, and headset, type H-75/AIC. The microphones, connected in parallel, feed a transistor amplifier and the audio output is supplied to the headsets, also connected in parallel. Additional audio can be supplied to the transmitters. The interphone amplifier is located in control box, type C-824A/AIC-10. This control box has been especially modified to operate with two microphones and headsets simultaneously. In addition to housing the interphone amplifier, the control box acts as a switch panel to

FIGURE 9A - Communications Equipment For Manned Balloon Flights WADC Gondola

FIGURE 9B - Communication Equipment Rack For Manned Balloon Flights

select the transmitter to be used for communication. Figure 10 shows location of all units and switches. A selector knob on the panel is positioned to obtain the desired operation as follows:

"OFF"	The interphone system does not function.
"INTER"	Pilot and co-pilot can communicate with each other. A push-to-talk switch is not required to be operated – thus, providing a "hot mic" system. Voice radio transmissions cannot be made when switch is in this position.
"VHF"	Interphone audio is supplied to the modulator of the VHF transmitter and if the push-to-talk switch is operated voice transmissions can be made by either operator on the selected VHF Frequency.
"HF"	The HF transmitter is normally transmitting the gondola altitude by automatic keying from the altitude coder, but in this position the code function is terminated and voice modulates the transmitter when the push-to-talk switch is operated.
"VHF/HF"	Simultaneous voice modulation of the VHF and HF transmitters occurs in this position when the push to talk switch is operated. Across the top of the interphone control box two toggle switches are located to permit the operators to select the receiver audio signals, HF or VHF, to be present in the headsets. Both can be on if desired.
Transmitter Keying	A three-position switch located at the top middle section of the communications rack, controls keying of the transmitter(s). In the off position the transmitter(s) are not keyed. In the down position the selected transmitters are keyed as long as the switch is held in this position. The switch is spring loaded and will return to the off position if not held. In the up position the transmitter(s) are keyed and the switch will stay in this position unless moved. This allows the operators to have free hands and yet transmit.

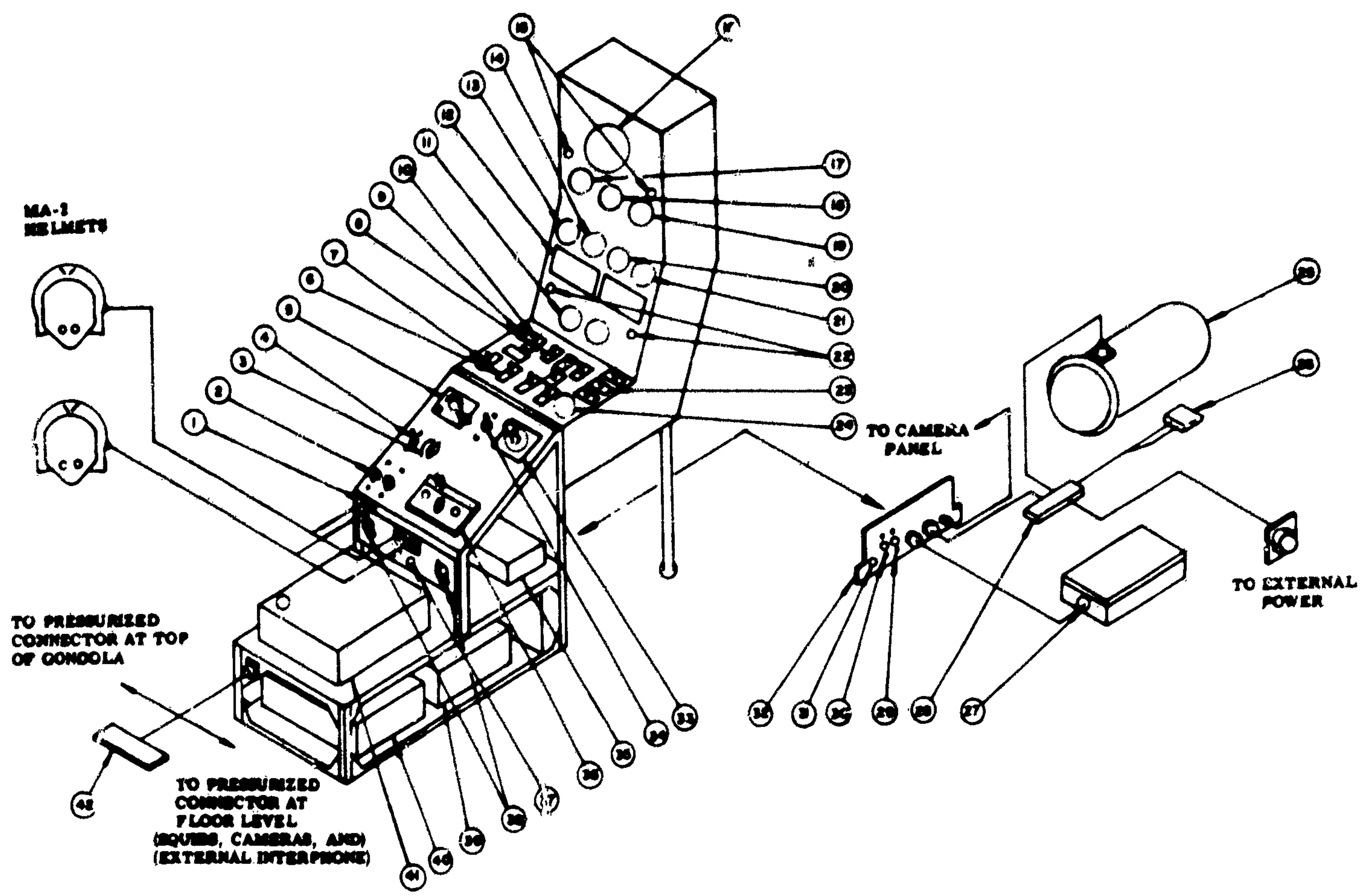


FIGURE 10 - Switch Location Diagram: Communications and Power Equipment — WADC Balloon Gondola

1. MIC HEADSET PLUGS
2. RADIO SET CIRCUIT BREAKERS
   1. VHF SET
   2. HF SET
3. VOLUME CONTROL - INTERPHONE
4. HF RADIO ON-OFF SWITCH
5. VHF RECEIVER TUNING CONTROL
6. MANUAL EMERGENCY CUT-DOWN
   1. TRAILING WIRE ANTENNA C. D.
   2. BALLOON - GONDOLA SEPARATION C. D.
   3. PARACHUTE DEPLOYMENT
7. BALLAST SWITCHES
8. MANUAL CUT-DOWN SWITCH — "UP" IS OFF, "DOWN" IS ON AND C. D. SEQUENCE BEGINS
9. GREEN LAMP LIGHTS WHEN RADIO CUT-DOWN SWITCH IS IN READY POSITION
10. RADIO CUT-DOWN SELECTOR SWITCH — "UP" IS SAFE, "DOWN" IS READY
11. OXYGEN QUANTITY GAGE
    1. PILOT
    2. CO-PILOT
12. OXYGEN CYLINDER PRESSURE
    1. PILOT
    2. CO-PILOT
13. ALTIMETER — 0 - 50 K FT INSIDE
14. INSIDE TEMPERATURE
15. LARGE RED JEWEL LAMPS CONNECTED IN PARALLEL — BOTH LIGHT UP TO INDICATE C. D. CIRCUIT IS IN OPERATION
16. ALTIMETER — 50 K - 100 K FT
17. ALTIMETER — 0 - 50 K FT OUTSIDE
18. OUTSIDE FREE AIR TEMPERATURE
19. RATE OF CLIMB
20. EIGHT DAY CLOCK
21. HUMIDITY INDICATOR AND "ON - OFF" SWITCH
22. TO PREVENT CUT-DOWN PRESS EITHER BUTTON
23. CAMERA SWITCHES — CAMERA HEATERS
24. B-9A INTERVALOMETER
25. MAIN BATTERY BOX - 28 VOLTS
26. 12 VOLT EMERGENCY CUT-DOWN BATTERY
27. AUXILIARY BATTERY BOX - 28 VOLTS
28. BATTERY TERMINAL BOARD
29. CIRCUIT BREAKER - 5 AMP
30. CIRCUIT BREAKER - 35 AMP MAIN POWER
31. MAIN - AUXILIARY POWER SWITCH
32. POWER PANEL - PART OF JUNCTION BOX
33. VHF TRANSMITTER CHANNEL SELECTOR
34. LEVER SWITCH - PUSH TO TALK
35. CUT-DOWN DELAY GENERATOR
36. RECEIVER, TRANSMITTER AND INTERPHONE CONTROL
37. HEATER CIRCUIT BREAKERS
38. HELMET DEFROST HEATER CONTROLS
39. VHF EQUIPMENT
40. TWO CHANNEL PHYSIOLOGICAL TELEMETERING EQUIPMENT
41. HF EQUIPMENT AND CUT-DOWN DECODER
42. TERMINAL BOARD - MOUNTED ON WALL OF GONDOLA, TERMINATING POINT FOR ALL EQUIPMENT NOT MOUNTED ON THE RACK OR INSTRUMENT PANELS

VHF Receiver

This receiver type R-19 is a part of the ARC-12 system. Manual tuning is accomplished by means of a control located at the upper left hand corner of the communication and control rack, tunable from 118 mc to 148 mc. Receiver audio gain and "ON-OFF" is controlled by a single knob located on the receiver control panel. Communcations audio is supplied to the interphone system and audio tone pulses are supplied to the cut-down decoder.

VHF Transmitter

This is a five-channel crystal controlled two-watt transmitter ARC type T-11B. Channel selection is by means of a selector knob located at the upper right hand corner of the communication and control rack. The four channels being used are set up on the following frequencies:

121.5 mc - Emergency
123.5 mc - Communications
126.18 mc - Towers
142.38 mc - Supporting Aircraft

This transmitter is normally operated broad band so that the power output on any one frequency is not as great as it could be. Transmitters to be used in the gondola have been adjusted for optiumum operation on the 123.5 mc frequency. Broad band the average power on each channel is about 0.5 watt. By peaking the transmitter at 123.5 mc, 1.5 watts is available with approximately 0.75 watts available at 121.5 mc, 126.18 mc and 142.38 mc. To permit operation at 100,000 feet the B+ change-over relay was replaced with a hermetically sealed unit. Tests at 100,000 feet with a transmitter so modified were satisfactory.

HF Transmitter, Receiver, and Power Supply

The high frequency 6425 KC transmitter, 2229 KC receiver and transistor power supply mount on the top shelf of the communication and control rack. The transmitter is a crystal controlled CW altitude coded DF tracking beacon that can be voice modulated if necessary and is normally keyed by the altitude coder. Keying is in the form of code letters. Provision has been made to voice modulate with speech clipped and filtered audio. The CW RF output is approximately 8 watts. An inline Zepp antenna 228 feet long radiates the power.

The HF receiver is a single-channel crystal-controlled superheterodyne fed by 36-1/2 feet of trailing wire antenna. The unit functions as a standby communication link and cut-down system. Audio is supplied to the interphone system and cut-down decoder.

A transverter type power supply operating from 24 volts supplies plate power for these units. Power transistors chop the 24 VDC and it is then applied to a transformer, rectified by transistors and filtered.

Cut-Down Decoder

This unit accepts audio independently from the VHF and HF receivers. If the correct code is available from either RF carrier the unit will close a relay which can be used to automatically start the cut-down sequence. If a 271.5 cycle tone is available for five seconds or longer and a second tone of 368.5 cycles for five seconds or longer is received the cut-down sequence will start.

The cut-down decoder is contained in the HF transmitter, HF receiver, transverter package (Fig 10).

Control

Position and motion indicating aircraft instruments are mounted on the vertical panel of the centrally located console. These include rate of climb indicators, altimeters (both low and high altitude range), an 8-day clock, temperature and humidity indicators, and oxygen cylinder pressure and quantity gage.

Climate control may be operated by either pilot or co-pilot. All switches and other means of controlling these functions have been mounted on the instrument console or within arms length of either occupant in a sedentary position.

Physiological Telemetering

A two channel electrocardiograph telemetering system (Fig. 9B and 11) is mounted on the lower shelf of the communication and control rack. This system consists of a Bendix type TXV-11 Transmitter, two Bendix type TOE-9 Voltage Controlled Oscillators and two EKG Pre-Amplifiers. The crystal

FIGURE 11 - Electrocardiograph Telemetering Equipment For Manned Balloon Flights

FIGURE 12 - Cut-Down Code Generator and Ground Communications Equipment Control For Manned Balloon Flights

controlled transmitter operates on 217.5 mc. The RF carrier is FM/FM modulated with two subcarriers at 7350 cps and 10,500 cps, plus or minus 7-1/2 percent deviation. A transverter type power supply operating from 24 volts supplies plate power for the telemetering equipment.

The two battery packs, independent of the gondola primary power, are provided. One pack is made up of 18 HR-5 Silvercels to provide 24 volts, and the other of 16 HR-5 Silvercels connected in series parallel to provide 6.3 volts to the filaments.

Cut-Down System

Provision has been made for either manual or remote radio cut-down. For remote radio cut-down the operators must arm the radio switch. In the unarmed position sample code pulses can be sent from the ground (see Command cut-down code generator) and the operation of the relay in the Cut-Down Decoder can be detected by two red lights at the top of the vertical instrument panel of the communications and control rack (Fig 10). If the remote radio cut-down has been selected by the operators and the cut-down code received, the above mentioned red lights and green light on the left side of the horizontal instrument panel will glow. The green light will glow all the time to indicate the radio cut-down system has been armed. The operators then have five seconds to stop the automatic cut-down sequence. This can be done by pushing either of the re-set switches. The instant cut-down pulses are received from the decoder, a relay in the cut-down timer closes and stays closed until the re-set switches are operated. The instant this relay closes, a five-second and a ten-second time delay relay begins to operate. The first delay relay will fire after five seconds removing the HF transmitting antenna, then ten seconds after start the other delay relay fires cutting the balloon away from the gondola and arming the 20,000 feet aneroid. As the gondola passes through 20,000 feet the aneroid switch makes contact and fires the chute deploying squibs. The 20,000 feet aneroid is armed only after the radio cut-down switch has been positioned, the timer relay closed and the ten-second delay relay operated.

Manual cut-down can be achieved by positioning the manual switch. The cut-down sequence is started as described by the radio method. A cut-down system independent of the remote radio or normal manual is available. This system has an independent power source 12 volts dc and independent switches for each cut-down function.

Altitude Coder

This unit is mounted on the outside of the gondola. A small 24 volt, 5 rpm motor drives a drum which has conductive segments on its surface. As an aneroid bellows moves a contact across the rotating segments a "make" "break" type keying is available. The code generated is a function of altitude and is used to key the HF transmitter. The code is a series of three Morse letters.

Camera System

Twenty-four volts are provided the camera systems from the communication and control rack. Manual switches are located on the horizontal surface of the instrument panel. An intervalometer and five cameras with heaters are available for operation. A pulse type GSAP camera mounted between the two seats and focused on the instrument console funishes a record of flight conditions as recorded by instruments on the panel. Other cameras record bailout and descent of jumper, parachute deployment, etc.

Primary Power

Three battery packs are available. The main supply is made up of 18 LR-60 Silvercels having a capacity of 1620 watt hours. A single LR-60 Silvercel is available to operate filaments of the HF equipment. The auxillary pack is made up of 18 LR-20 Silvercels and has a capacity of 540 watt hours. A pack of 8 LR-20 Silvercels are provided for the 12-volt emergency cut-down power.

Command Cut-Down Code Generator

This unit (Fig. 12) provides voice audio and code audio signals to two ground transmitters. The appropriate code audio tones 271.5 cps and 368.5 cps radiated will cause the gondola cut-down decoder to operate. The generator is capable of driving two transmitters, HF and VHF, simultaneously. Provision is made for operation of two headset-microphones, type H-78A/AIC, in parallel. For operation of the headsets the unit accepts inputs from two receivers, HF and VHF. This is ground equipment and operates on 110-volts ac.

Mockup Studies

As soon as the cylindrical design was decided upon, a plywood mockup of the gondola interior was constructed. Mockup seats were constructed and the (actual) gondola instrument panel was installed. One of the largest crew members (99th percentile) was dressed in a partial pressure suit and helmet. The suit was inflated and the subject was seated in the mockup. The proper positions of the seats, the instrument panel, various controls, and windows were determined from these exercises. The subject maneuvered about the interior of the gondola in an inflated suit to determine the spatial requirements. By repeated exits through a doorway made smaller or larger by use of masking tape, a minimum size doorway was obtained.

The fact that the WADC design personnel were able to run through the exercise of actually determining the spatial requirements of the crew operating under vacuum conditions materially bettered the design.

Testing and Simulation

The results of the testing program seemed to generally bear out the validity of the engineering rule adopted for the gondola of designing to three times the expected load and testing to twice the expected load.

The first concern in the gondola testing was to establish the aerodynamic stability of the total gondola configuration and the proper shape of the fairings. Early testing was done in the Aeronautical Accessories Laboratory horizontal blower, using a wooden model (10:84 scale *) pinned by a shaft through the cg and free to rotate about the cg with one degree of freedom (Fig. 13). The model was tested for static and dynamic stability with and without the parachute. Various fairing shapes were tested and the best one selected on the basis of tuft studies of the airflow. The final design retained a nonseparated flow all the way to the top of the fairing, and left a five foot (full scale) wake into the parachute.

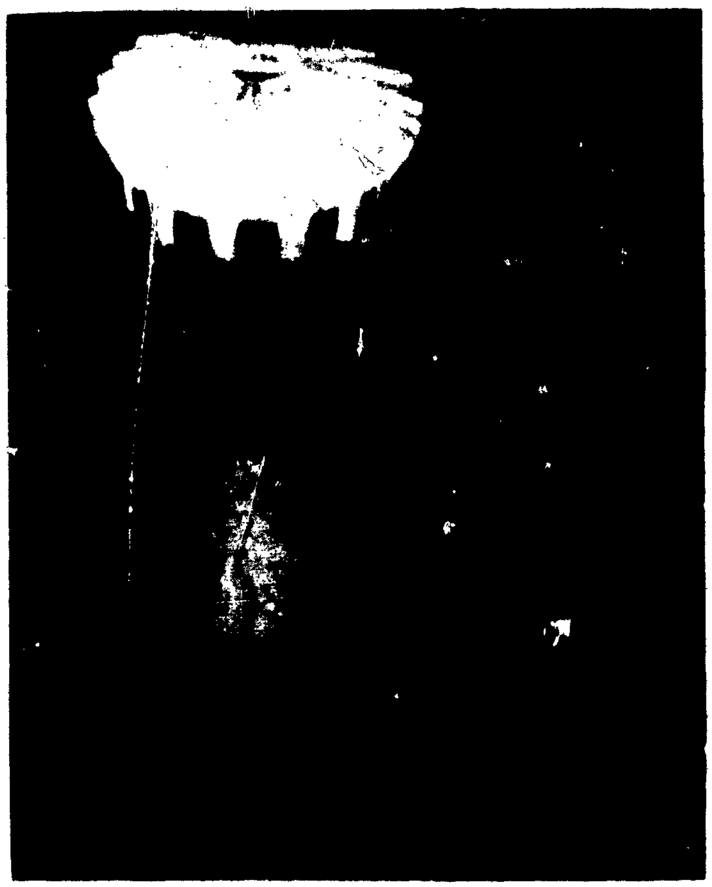


FIGURE 13 - Gondola Model in Horizontal Blower

A 10:48 scale model gondola was constructed to be dynamically similar to the full scale gondola under drogue chute descent at 30,000 feet (maximum simulated altitude attainable with the WADC vertical wind tunnel). The model was constructed of mahogany, balsa, Fiberglas, aluminum, and lead to scale up properly the moments of inertia (Fig. 14).

The tests indicated that the gondola configuration was aerodynamically sound, that the riser lengths should be three and one-half gondola diameters, that cg change had no apparent effect on stability, and that the gondola was stable with the hatch off, an added safety feature for the pilot. A model of the full size spherical dummy gondola (Fig. 3) was also flown in the vertical wind tunnel to determine the degree of correlation between what was observed in the tunnel and what was observed in actual flight. The correlation seemed rather good.

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* Selected because of the size of the available model of the guide surface stabilization parachute.

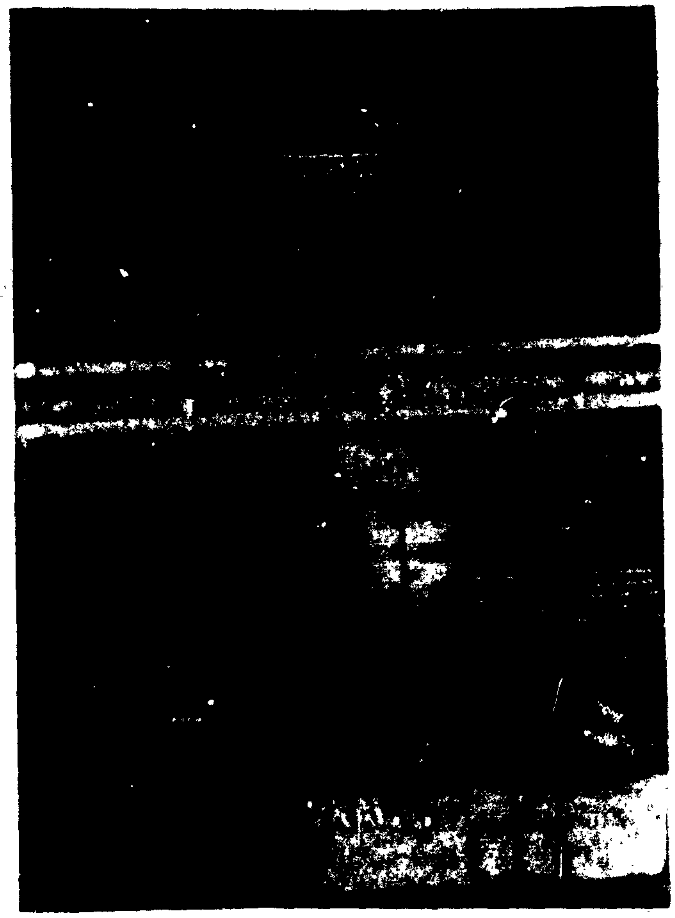

FIGURE 14 - Vertical Wind Tunnel Test Model

Static Test

After the construction of floor structure, landing gear, and seats, they were assembled for a static test of their integrity. The first test simulated the parachute opening shock load. The floor structure was supported by eight-inch blocks under the "c" ring on either side of the landing gear. The seats were considered to be supporting a load of 300 pounds of man and equipment during an 8 g opening shock. Actual loads in the seats were 2620 and 2670 pounds (Fig. 6). The actual total load on the seat structure was approximately 5600 pounds. Since the "c" ring was not continuously supported as it would have been in flight, it buckled elastically in six places (Fig. 15). Total vertical deflection of the center of gondola floor structure was 9/16 of an inch. It was decided to reinforce the "c" ring with additional stiffeners as a precautionary measure.

A landing load test was made next (Fig. 16). The seats were removed, and dummy legs inserted into the landing gear. The legs rested on plates which rested on rollers. The legs were connected to hydraulic struts to impose bending loads (such as might be caused by a landing in high winds). Nine thousand and six hundred pounds of lead shot bags were arranged in "fort" fashion on the structure. The assembly was then lowered by jacks to the floor where the legs supported the load and produced moments into the structure. With a 9600-pound load (representing 80% of design load, or an empty gondola encountering a 12.8 g landing) excessive deflections of the floor structure were noticed and the test was halted.

FIGURE 15 - Floor Structure Deflection Under Static Load

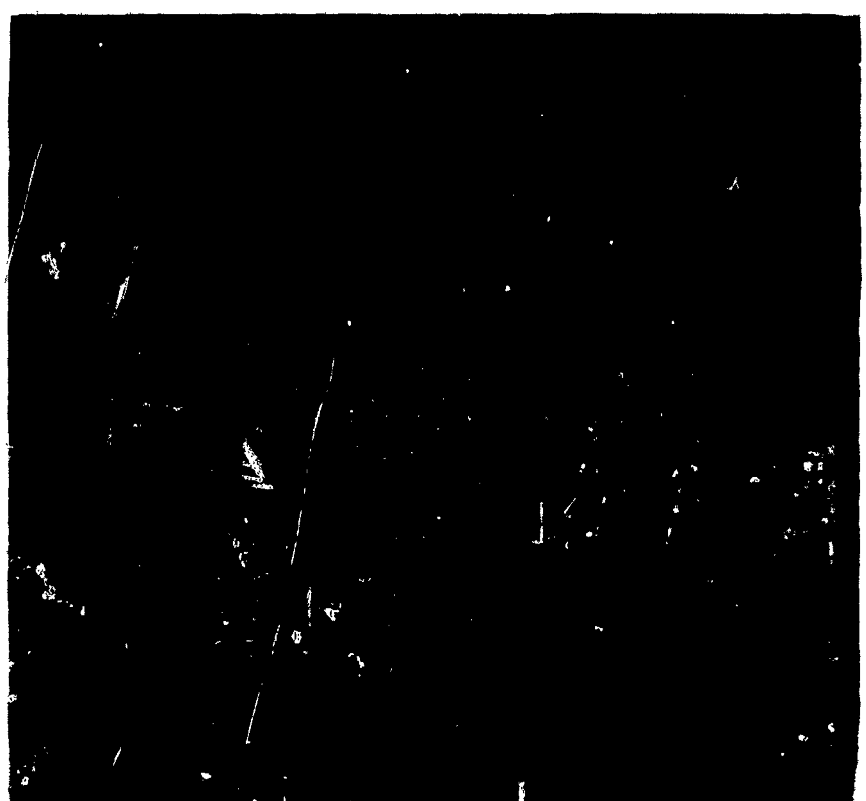

FIGURE 16 - Simulated Landing Load Test

Superficial examination did not disclose failure, but it was felt advisable to halt the vertical loading. With the 9600-pound vertical load, the gondola structure was elevated by hydraulic struts tied to the top of the landing gear restraint tubes. The legs were pulled by the hydraulic struts attached at the bottom to simulate a side force on landing. A sidewise moment 32% of the limit load was applied and tests were again halted and all loads removed due to excessive deflection of the floor structure in two areas.

The failure occurred in the following manner. The load caused the whole structure to rotate about the rigid gusset plate area, buckling the top of the main beam and the channel rig (Fig. 17). The error in design was in that the load was introduced into a non-rigid structure attached to a rigid structure. On the area near the seat, a small gusset of 0.051 aluminum alloy prevented the failure under identical loads (Fig. 18).

The fix consisted in bringing the landing loads across the gusset plate and tying the structure together more completely. A static test of the total gondola structure undergoing a seven g opening shock was conducted. The gondola was suspended by a test harness of nylon webbing attaching to the riser connection points. Six thousand and two hundred pounds of lead shot bags were evenly distributed over the gondola floor. No signs of buckling or yielding were noticed anywhere on the structure. The test was terminated due to a failure in the test harness, but it was essentially complete at termination.

Additional static tests were conducted with the top fairing attachments and the bag attachments in straight tension to ultimate loadings. All attachments were found to be satisfactory.

Pressure Testing

The first design of the bottom pressure bag employed only one bag made of eight panels. The pull-up patches (attachments to enable the bag to be pulled flat against the floor for landing gear clearance) were constructed in such a way that bolts were passed through reinforced sections of the bag. The entire assembly weighed about fourteen pounds.

It was decided to test the gondola under water to reduce the damage that an explosive failure would cause in air. Originally it was planned to sink the gondola in water and add air to pressurize the interior. However, it was found that almost any air addition was sufficient to float the gondola, so that pressure was increased by water addition - a difficult process.

The gondola remained in water overnight due to the difficulties encountered in filling out the volume with water. By the next day the adhesively bonded strips had started to peel off the bag, particularly in the bottom patch region. The gondola was pressurized to 1.5 psig and the bag split at the bottom, through the bottom bolt hole and up the middle of the panels.

FIGURE 17 - Failure Mode of Floor Structure

FIGURE 18 - Location of Gusset Preventing Failure

Upon inspection, the failure was found to have originated in the stress concentration around the bottom bolt hole (1/4 inch diameter). This failure propagated along the line where the cover patches lined up. Inspection disclosed that the fabricators had deviated from the drawings.

The test showed: (1) Large holes in the pressure bag should be avoided, since they cause stress concentrations. (2) Quality control and inspection during manufacture was essential, to avoid faulty construction. (3) Water pressure test was unsatisfactory for this application, due to material deterioration and the time and trouble involved.

A new bag (see section on Bottom Pressure Bag) was designed and constructed, and on trial inflation it was found to be misassembled and it was reworked.

The new test setup consisted of placing the gondola on its launch cart, and towing it and a portable air compressor to an isolated area. Precautions were taken to shield the testing personnel against an explosive failure (Figs. 19, 20).

On the first outdoor test the pressure was increased to six and one-half inches of mercury. At this point the leakage rate was equivalent to the compressor delivery rate. Upon close examination the bottom bag was found to show some failure at the bottom seam due to insufficient manufacturing edge margin. The high leakage was caused by breakaway of the bag sealing tape and a breakdown of the improvised hatch gasket.

Succeeding tests showed that the gondola could withstand 7 psig or 125% of operational pressure, but that sealing the bag area would be very difficult.

It was finally decided to forget the sealing problem and go ahead with a test of structural integrity. A very large capacity compressor was obtained and the test was re-run. The compressor capacity was so far greater than anticipated, however, that 10 psig was obtained in the gondola before the operator could reduce the amount of air being delivered. The air was shut off and a rapid pressure dop plus a slight pinging noise (characteristic of snapping nylon thread) were observed. The bag then failed violently.

Bag failure probably occurred between 7 and 10 psig and consisted of thread breakage in the seams causing disproportionate loading. It was decided to abandon the bag concept because of inherent difficulties of sealing and quality control in construction. It is felt that the fabric pressure barrier does have potential merit in other pressure bulkhead applications, however.

The bag was replated by the structure described earlier and, upon pressure test to 10 psig, no failure was observed.

Various runs were made at 10.5 inches of mercury to stop the remaining leakage in the gondola. The leakage was finally reduced to an impreceptible level. (No pressure drop noticeable during the flight period.) It was found

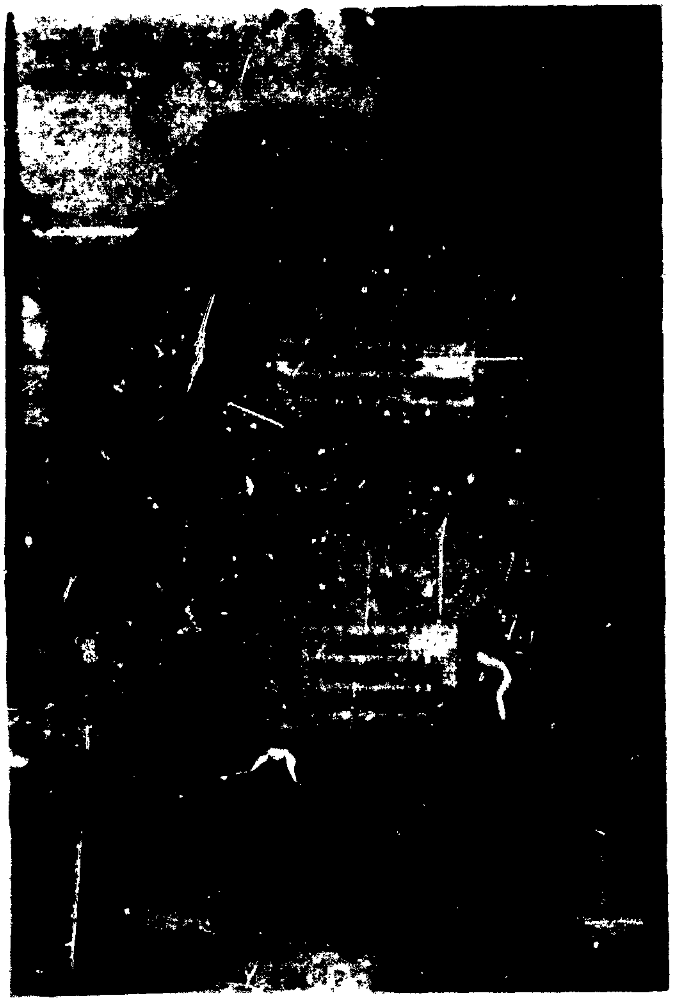

FIGURE 19 - Gondola Ready For Pressure Test With Fabric Bag

FIGURE 20 - Pressure Test Setup

that the only satisfactory method of detecting leaks is to station an observer inside the gondola. The special silicone rubber flap seal for the hatch worked perfectly.

Temperature Testing

It became apparent early in the program that temperature control would be a problem. The gondola passes through three regions of different heat transfer in flight, even assuming a flight of sufficiently short duration to ignore the affects of change in sun location. These regions are: (1) Ascent through the troposphere, or radiative heat transfer plus convective heat transfer through constantly cooler air, (2) Ascent through the stratosphere, or radiative heat transfer plus convective heat transfer through more or less constant temperature air, and (3) Float, or almost pure radiative heat transfer. Since the sun, earth, and sky provide great sources and sinks of thermal energy, it should be possible to achieve any desired internal temperature for a short flight by the proper external coating. Previous flights have used insulation to combat convective heat losses on ascent, but it was believed that by accepting a fairly high float temperature, this could be eliminated. It was decided to paint the gondola dull black on the bottom fairing and dull white on the top sides. This finish was checked out on General Mills "hitch-hike" flights (see G.M. Report B-1045-Ref. 3) by a temperature model gondola.

The question arose as to whether a subject could function well under the proposed temperature range. The data from the temperature gondola flights was modified to fit Holloman conditions and a run was made in a controlled temperature chamber with one of the crew in flight gear.

The temperature profile simulated an early morning take-off, a rise through the stratosphere with temperatures dropping below freezing, a long float (for Project High-Dive), with a temperature rise to 60°F and a sudden drop to -67°F on parachute descent then a rise to 80° F on the desert floor. The subject functioned well all the way through and exhibited no undue discomfort.

Altitude Chamber Runs

After the outfitting of the gondola was completed, it was placed in the Weapons Guidance Laboratory Stratosphere Chamber in order to conduct mission profile runs with the crew. The gondola and crew were completely equipped except for items which, if actually used, would cause needless confusion in the chamber such as gondola parachutes, pyrotechnics, ballast, etc. Operation of the essential systems was indicated by flash bulbs. The first three runs were made on external power supply, the last with the gondola's silver cells.

The mission profile was as follows:

(1) The subjects were dressed and started to pre-breathe.

(2) The lox convertors were filled, the air conditioner was readied.

(3) The subjects entered the gondola and were hooked up to their EKG leads and oxygen lines (Fig 21).

(4) The hatch was put on.

(5) The gondola was purged (one hour's time).

(6) The convertors were filled.

(7) The chambers were closed.

(8) The chamber ascended at 500 feet/min to float (about 80,000 feet).

(9) Various simulated emergencies and operational communications were given the crew during ascent and float.

(10) The crew depressurized.

(11) The jumper exited.

(12) The pilot cut down (descent at about 10,000 feet/min).

(13) The pilot deployed the main parachute at 20,000 feet and then exited.

(14) The chamber was brought to ground level.

The runs showed the need for thorough crew familiarization with the system. They also disclosed the need for minor equipment modification and various hand-holds and shelves in the gondola interior.

Balloon Flight Test

The gondola was specially fitted with a sequencing package by WCLEH that tied into the gondola electrical system and provided the various "pilot" functions (cut-down, parachute deployment, camera starting) necessary for a balloon flight. The gondola and launch cart were then air-lifted to AFMDC for flight test.

The gondola was launched with a 166-foot balloon (Figs. 22 through 28) and made a sucessful flight to 96,000 feet and a stabilized descent. The gondola

carried a dummy aloft to simulate a jumper (Fig. 24). The sequencing package failed to provide several commands and as a result most of the cameras failed to function and the riser releases failed to fire.

The balloon did not burst when the dummy (300 pounds) left the gondola. The gondola cut down and started a slight oscillation which damped to zero by 60,000 feet. The main chute deployed perfectly with very little opening shock. The landing gear jammed due to faulty design and caused a landing shock in excess of 20 g and consequent heavy, but repairable damage.

The landing gear failed due to the jamming action of the chip shoved between the tool steel cutter and the 61ST6 holder and the consequent failing of the softer 61ST6 holder. This defect has been remedied by making a removable steel tool holder designed to break the chip.

The flight test operation showed the need for the following techniques in the event of manned flight:

(1) All non-essential range coverage requests should be labeled as such to prevent the cancellation of some non-essential coverage automatically cancelling the whole flight.

(2) There should be multiple transportation systems, both air and ground, for key personnel to cover unforseen vehicle breakdown at crucial periods.

(3) There should be a reserve helicopter committed to the project.

(4) Trajectory predictions should not be relied upon to provide absolute information, but only indications.

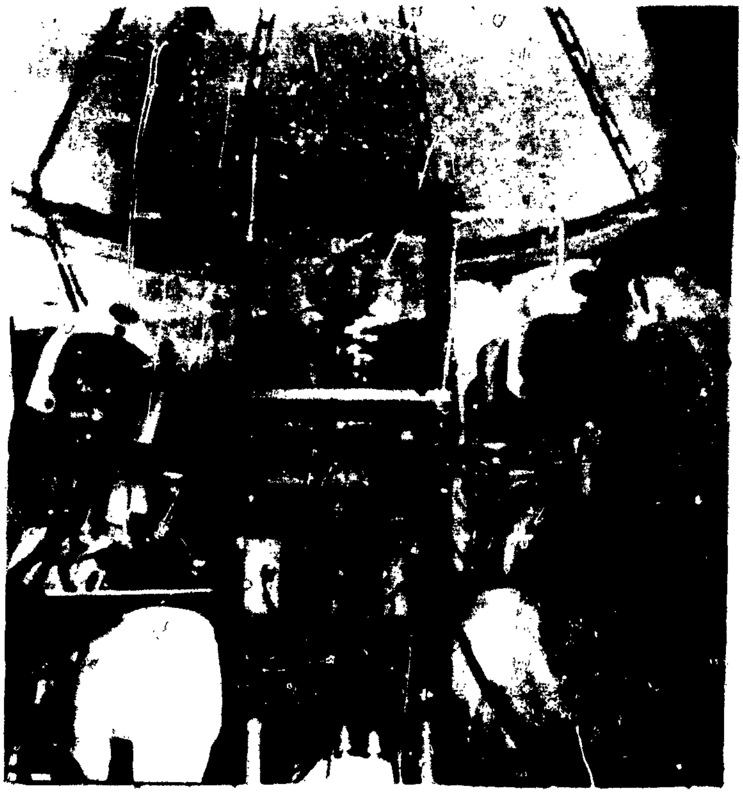

FIGURE 21 - Subjects Being Prepared for Altitude Chamber Runs

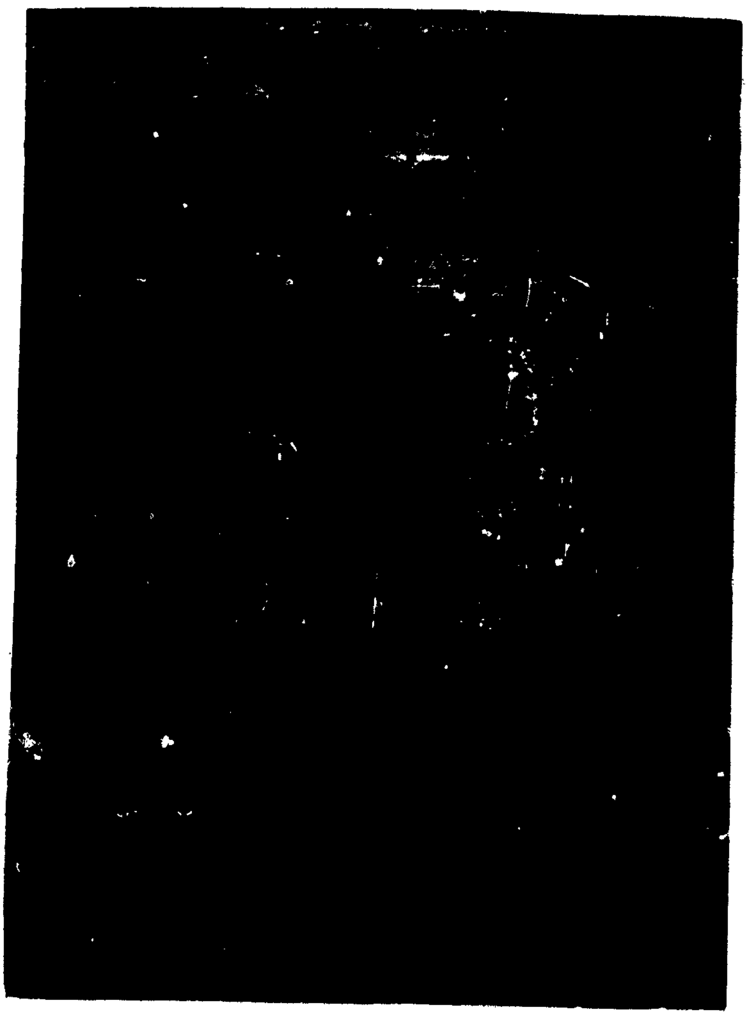

FIGURE 22 - Gondola Prepared for Unmanned Test Flight

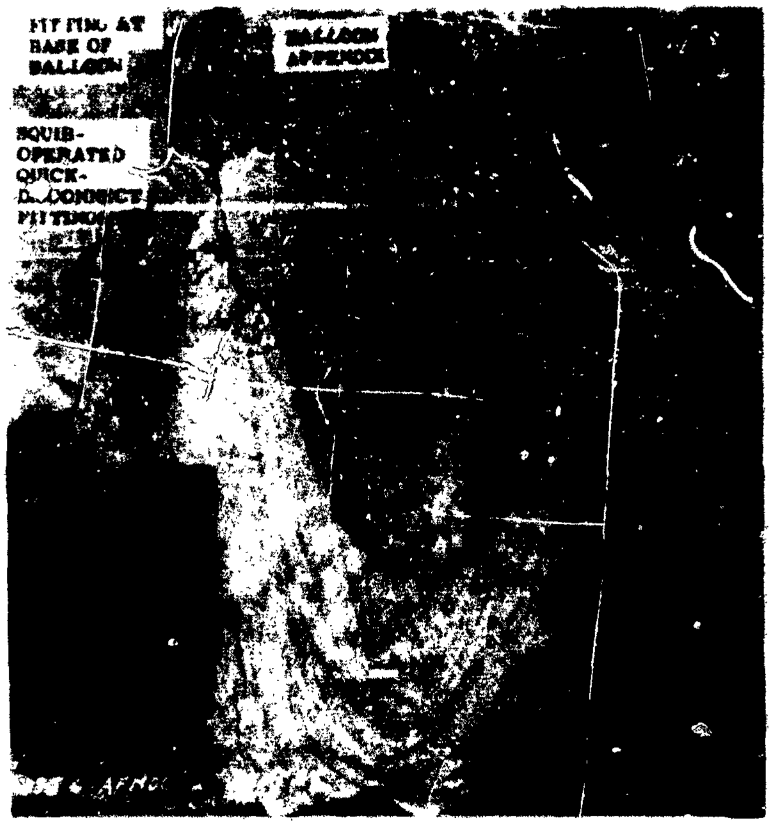

FIGURE 23 - Connection of First-Stage Parachute to Balloon

FIGURE 24 - Dummy Positioned To Simulate Jumper

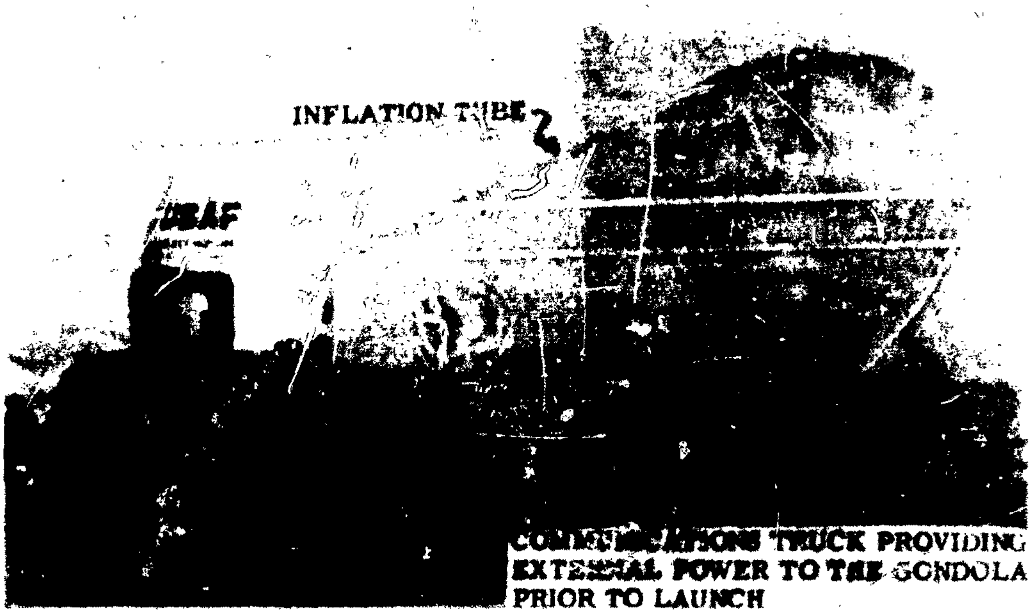

FIGURE 25 - Initial Inflation

FIGURE 26 - Vertical Inflation and Launch

FIGURE 27 - Balloon and Gondola Ascending

FIGURE 28 - Gondola Being Recovered After Landing

CONCLUSION

In general, this vehicle development showed the advantages of a mission-oriented approach to the design of a system. Once the overall mission profile was established, the various requirements and resulting designs seemed to follow naturally even when the final designs were somewhat unorthodox.

Although this balloon gondola was built with a specific mission in mind (high altitude bailout tests), it appears suitable for use in other research programs requiring a high-altitude manned platform. At the present time it is being considered as a means of conducting astronomical research at high altitudes for the purpose of establishing criteria for future astronomical systems in both balloon and space vehicles.

It is hoped that the work outlined in this report will contribute to any future development of manned balloon systems, especially in the areas of weight-saving and structural design.

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